Solution of Experimental Problem No.2

Black box

1. The type of the elements *Z*

Adjust the oscilloscope to obtain the same gain for the two channels. Use the sine wave from the generator.

Use the circuit in Figure 1 to determine the type of the elements.

We find finally:

Z_3, Z'_1 and Z'_2 are resistors and

$Z'_1 = Z'_2 = 2\,Z_3 = (10.0 \pm 0.5)$ kΩ

Z_1, Z_2 and Z'_3 are capacitors, and

$C_1 = C_2 = \frac{1}{2} C'_3 = (47 \pm 2)$ nF

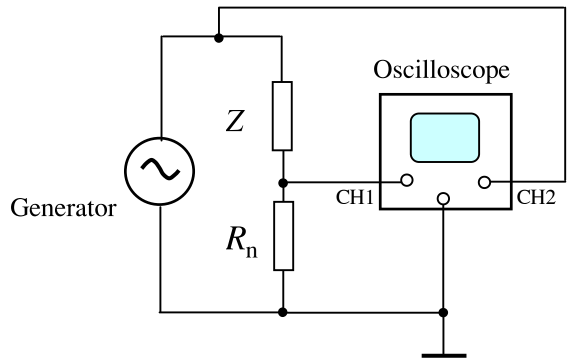

Figure 1

2.

a. The electric circuit of the black box DD'A' is shown in Figure 2.

b. Apply a sine wave signal to connectors D and A'. Connect D and A' to channel 1 (CH1) and D' and A' to channel 2 (CH2).

The ratio $K = \frac{U_{D'A'}}{U_{DA'}}$ is determined from the amplitudes of the signals $U_{D'A'}$ và $U_{DA'}$. The phase shift φ can be determined directly from the traces of the signals (or from the Lissajous patterns).

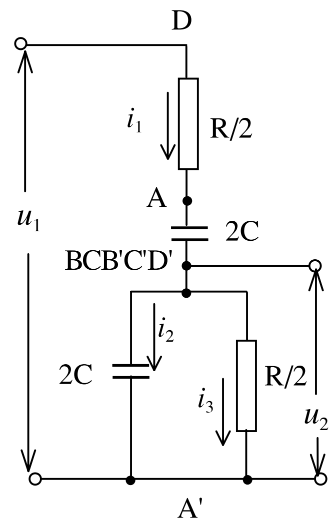

Figure 2

Tabulating K and φ versus f, we get for example:

f	100	150	200	300	330	400	600	800
K		0.29	0.30	0.32	0.33	0.32	0.3	0.28
φ	44	28	16	2	0	-8	-24	-38

The experimental error of f is ± 1Hz, of φ is $\pm 5^0$ and of K is ± 0.02.

Here are the plots of K and φ as functions of f.

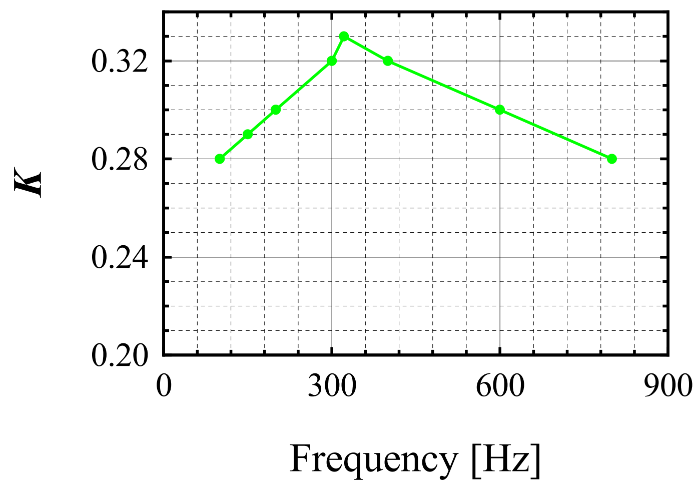

Figure 3

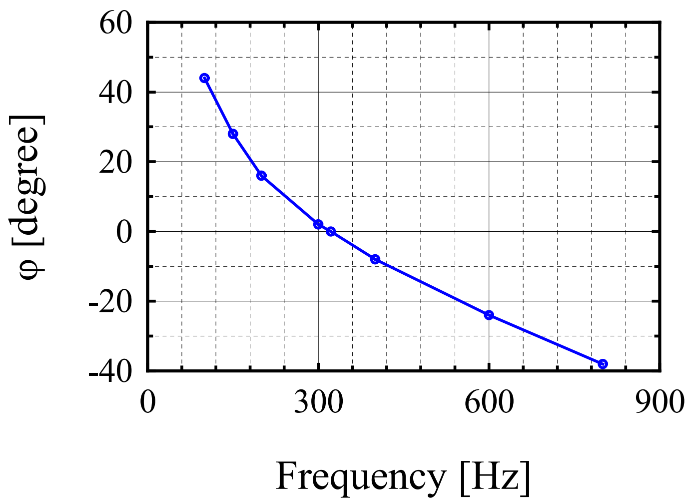

Figure 4

c. The graphs possess a particular point at f_0 = 330±1 Hz, at which φ equals zero and K has a maximum of K=0.33 ±0.01. φ changes its sign from positive to negative with increasing of the frequency f across f_0.

The value of f_0 may vary from 325 Hz to 335 Hz depending on the set of experiment, due to the deviation in the value of the resistance and capacitance in the set.

d. The phasor diagram for the circuit is shown in Figure 5 , where u_1 is the instantaneous voltage between D and D' , and U_1 - its amplitude.

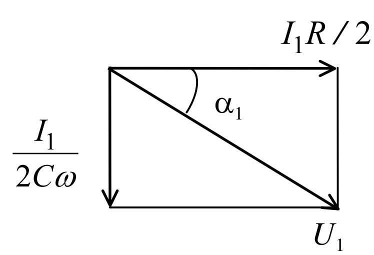

Figure 5

We have $\tan\alpha_1 = \frac{1}{\omega CR}$ and $U_1 = I_1\sqrt{\left(\frac{R}{2}\right)^2 + \frac{1}{4C^2\omega^2}}$

For the D'A' parallel cicuit, $i_1 = i_2 + i_3$, and the phasor diagram is shown in Figure 6. u_2 is in phase with i_3.

$\tan\alpha_2 = \frac{I_2}{I_3} = \omega.2C.R/2 = \omega CR$. Let u_2 the voltage between D' and A' , we have $I_3 = \frac{U_2}{R/2}$; $I_2 = U_2.2C.\omega$. Hence:

$$U_2 = I_1.\frac{1}{\sqrt{\frac{1}{\left(\frac{R}{2}\right)^2} + 4C^2\omega^2}}.$$

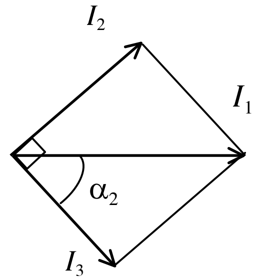

Figure 6

By combining Figure 5 and Figure 6, we obtain Figure 7, with $u = u_1 + u_2$ being the instantaneous voltage between D và A'.

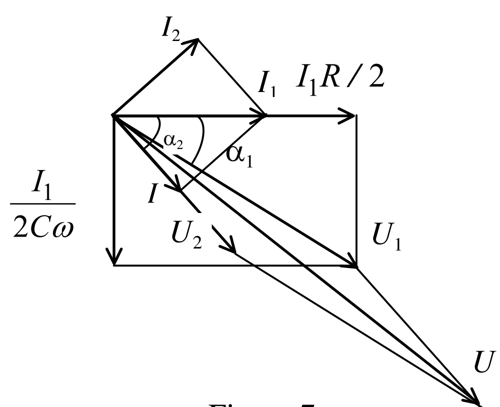

Figure 7

For $\omega = 2\pi f = \frac{1}{CR}$, $\tan\alpha_1 = \frac{1}{\omega CR} = \tan\alpha_2 = \omega CR$. In this condition, u_1 , u_2 and u are in phase, so that $\varphi = \alpha_2 - \alpha_1 = 0$. Hence $K = \frac{U_{D'A'}}{U_{DA'}} = \frac{U_2}{U_1 + U_2}$. Substituing $\omega = \frac{1}{CR}$ into U_1 and U_2 , we obtain $K = \frac{1}{3}$.

That is, for $f_0 = \frac{\omega}{2\pi} = \frac{1}{2\pi RC} = \frac{1}{2\pi.10^4.48.10^{-9}} = 331$ Hz, $K = \frac{1}{3} = 0.33$, $\varphi = 0$, which is observed in the experiment.

For $\omega \neq \frac{1}{CR}$, u_1 and u_2 are out of phase, and K has values smaller than 1/3.